CLAIMS

1. Apparatus for compressing at least one chamber of a heart of a patient's body, the apparatus comprising:

one or more inflatable elements;

a pump in fluid communication with the inflatable elements; and

at least one band having a first one or more first portions and second one or more second portions, the first and second portions alternatingly arranged,

the first one or more first portions and second one or more second portions having respective variable first and second total lengths,

the first one or more first portions adapted to be placed around at least a portion of the heart in mechanical communication with the portion of the heart, and

each of the second portions placed around at least 180 degrees of a periphery of at least one of the inflatable elements, such that the second portions are in mechanical communication with the heart via the first portions, and such that when the inflatable elements are inflated by the pump the first total length decreases by an amount that the second total length increases.

2. The apparatus according to claim 1, wherein the first one or more first portions are adapted to be disposed between the heart and the one or more inflatable elements.

3. The apparatus according to claim 1, wherein the one or more inflatable elements comprise respective balloons.

4. The apparatus according to claim 1, wherein the one or more inflatable elements comprise respective piston and cylinder arrangements.

5. The apparatus according to claim 1, wherein the pump is adapted to pump a liquid to inflate the inflatable elements.

6. The apparatus according to claim 1, wherein the pump is adapted to pump a gas to inflate the inflatable elements.

7. The apparatus according to claim 1, wherein, for each inflatable element, only one second portion is placed around at least 180 degrees of its periphery.

8. The apparatus according to claim 1, wherein the inflatable elements are coupled to the band such that when the first one or more first portions are placed around the portion of the heart, the inflatable elements are symmetrically disposed around the heart.

9. The apparatus according to claim 1, wherein the inflatable elements are coupled to the band such that when the first one or more first portions are placed around the portion of the heart, the inflatable elements are asymmetrically disposed around the heart.

10. The apparatus according to claim 1, wherein the band comprises a tab portion adjacent to one of the inflatable elements, and wherein the band is shaped to define at least one slit thereof adjacent to the one of the inflatable elements, and wherein the tab is adapted to move within the slit responsive to inflation of the one of the inflatable elements.

11. The apparatus according to claim 1, wherein the band is adapted to be aligned in parallel with a local muscle fiber direction of the heart.

12. The apparatus according to claim 1, wherein the band is adapted to be aligned perpendicularly to a local muscle fiber direction of the heart.

13. The apparatus according to claim 1, wherein the band is adapted to be aligned at a divergence of between 20 and 70 degrees from a local muscle fiber direction of the heart.

14. The apparatus according to claim 1, comprising an inner layer, adapted to be disposed between the band and the heart, and at least one hook, adapted to secure the inner layer to the heart.

15. The apparatus according to claim 1, comprising a diastole-supporting mechanism, adapted to store energy from the pump during systole, and to release the energy during diastole in a manner that facilitates application of an outwardly-directed force to an epicardial surface of the heart during diastole.

16. The apparatus according to any one of claims 1-15, wherein the at least one band comprises a plurality of bands.

17. The apparatus according to claim 16, wherein at least two of the plurality of bands are parallel.

18. The apparatus according to claim 16, wherein at least two of the plurality of bands are mutually perpendicular.

19. The apparatus according to claim 16, wherein at least two of the plurality of bands diverge by an angle of less than 30 degrees.

20. The apparatus according to claim 16, wherein at least two of the plurality of bands diverge by an angle that is between 30 degrees and 45 degrees.

21. The apparatus according to any one of claims 1-15, wherein the apparatus comprises an apical-region cover, coupled to the band and adapted to cover a region in a vicinity of an apex of the heart.

22. The apparatus according to claim 21, wherein the apical-region cover is adapted to be disposed on the heart such that the vicinity of the apex of the heart does not include the apex.

23. The apparatus according to claim 21, wherein the apical-region cover is adapted to cover the apex of the heart.

24. The apparatus according to claim 21, wherein the apical-region cover is adapted to passively apply a compressive force to the vicinity of the apex of the heart.

25. The apparatus according to claim 21, wherein the apical-region cover is adapted to passively apply a compressive force to the apex of the heart.

26. The apparatus according to claim 21, wherein the apical-region cover is adapted to actively apply a compressive force to the vicinity of the apex of the heart.

27. The apparatus according to any one of claims 1-15, wherein at least one of the second portions comprises at least one flexible line, which is wrapped at least twice around the periphery of at least one of the inflatable elements.

28. The apparatus according to claim 27, wherein the at least one flexible line comprises a plurality of flexible lines, each wrapped at least twice around the periphery of the at least one of the inflatable elements.

29. The apparatus according to any one of claims 1-15, wherein at least one of the second portions comprises one or more flexible lines, each flexible line adapted to be placed around at least 180 degrees of the periphery of at least one of the inflatable elements.

30. The apparatus according to claim 29, comprising a feedthrough piece shaped to define at least one hole therein, and wherein the one or more flexible lines are adapted to pass through the at least one hole in the feedthrough piece.

31. The apparatus according to claim 30, wherein each flexible line passes through a respective one of the at least one hole.

32. The apparatus according to claim 29, wherein the one or more flexible lines comprises at least 2 lines.

33. The apparatus according to claim 32, wherein the plurality of flexible lines comprises at least 10 lines.

34. The apparatus according to claim 32, wherein the plurality of flexible lines comprises at least 25 lines.

35. The apparatus according to any one of claims 1-15, wherein, for at least one of the inflatable elements, at least two or more second portions are placed around at least 180 degrees of its periphery.

36. The apparatus according to claim 35, wherein the two or more second portions comprise three or more second portions.

37. The apparatus according to any one of claims 1-15, wherein the apparatus comprises a sleeve adapted for placement around the heart, and wherein the band and the inflatable elements are disposed within the sleeve.

38. The apparatus according to claim 37, wherein the band is isolated by the sleeve from contact with tissue of the patient's body.

39. The apparatus according to claim 37, wherein a total mass of the sleeve including any fluid therein is less than 100 g at all phases of the heart contraction cycle.

40. The apparatus according to claim 39, wherein the total mass is less than 50 g at all phases of the heart contraction cycle.

41. The apparatus according to any one of claims 1-15, wherein a total mass of the apparatus is less than 300 g, and wherein the apparatus comprises a battery adapted to drive the pump for at least one hour without being recharged from a source outside of the patient's body.

42. The apparatus according to claim 41, wherein the battery has a capacity of less than 2 Amp-Hour.

43. The apparatus according to claim 42, wherein the battery has a capacity of less than 1.3 Amp-Hour.

44. The apparatus according to claim 42, wherein a total volume of the apparatus is less than 300 cc.

45. The apparatus according to any one of claims 1-15, wherein each of the inflatable elements is adapted to increase in volume by at least 0.1 cc in response to the inflation by the pump.

46. The apparatus according to claim 45, wherein each of the inflatable elements is adapted to increase in volume by at least 10 cc in response to the inflation by the pump.

47. The apparatus according to any one of claims 1-15, wherein each of the inflatable elements is adapted to increase in volume by less than 80 cc in response to the inflation by the pump.

48. The apparatus according to claim 47, wherein each of the inflatable elements is adapted to increase in volume by less than 50 cc in response to the inflation by the pump.

49. The apparatus according to any one of claims 1-15, wherein the one or more inflatable elements comprise exactly one inflatable element.

50. The apparatus according to claim 49, wherein the exactly one inflatable element is adapted to increase in volume by at least 5 cc in response to the inflation by the pump.

51. The apparatus according to any one of claims 1-15, wherein the one or more inflatable elements comprises a plurality of inflatable elements.

52. The apparatus according to claim 51, wherein the plurality of inflatable elements comprises two to three inflatable elements.

53. The apparatus according to claim 51, wherein the plurality of inflatable elements comprises four to five inflatable elements.

54. The apparatus according to claim 51, wherein the plurality of inflatable elements comprises greater than six inflatable elements.

55. The apparatus according to claim 54, wherein the plurality of inflatable elements comprises fewer than 50 elements.

56. The apparatus according to claim 55, wherein the plurality of inflatable elements comprises fewer than 25 elements.

57. The apparatus according to claim 51, wherein a total increase in volume of all of the inflatable elements in response to being inflated by the pump is greater than 5 cc.

58. The apparatus according to claim 57, wherein a total increase in volume of all of the inflatable elements in response to being inflated by the pump is greater than 10 cc.

59. The apparatus according to claim 58, wherein a total increase in volume of all of the inflatable elements in response to being inflated by the pump is greater than 15 cc.

60. The apparatus according to claim 59, wherein a total increase in volume of all of the inflatable elements in response to being inflated by the pump is 25 cc.

61. The apparatus according to any one of claims 1-15, wherein the apparatus is configured such that the decrease of the first total length is at least 8 mm.

62. The apparatus according to claim 61, wherein the apparatus is configured such that the decrease of the first total length is at least 40 mm.

63. The apparatus according to claim 62, wherein the apparatus is configured such that the decrease of the first total length is less than 150 mm.

64. The apparatus according to any one of claims 1-15, wherein when the inflatable elements are inflated by the pump during a cardiac cycle, a peak reduction in volume of the heart is at least 200% of a total volume of fluid pumped into all of the inflatable elements by the pump during the cardiac cycle.

65. The apparatus according to claim 64, wherein when the inflatable elements are inflated by the pump during the cardiac cycle, the peak reduction in volume of the heart is at least 1000% of the total volume of fluid pumped into all of the inflatable elements by the pump during the cardiac cycle.

66. Apparatus for compressing at least one chamber of a heart of a patient's body, the apparatus comprising:

one or more shape-changing members;

a control unit, coupled to the shape-changing members; and

at least one band having a first one or more first portions and second one or more second portions, the first and second portions alternatingly arranged,

the first one or more first portions and second one or more second portions having respective variable first and second total lengths,

the first one or more first portions adapted to be placed around at least a portion of the heart in mechanical communication with the portion of the heart, and

each of the second portions placed around at least 180 degrees of a periphery of at least one of the shape-changing members, such that the second portions are in mechanical communication with the heart via the first portions, and such that when the shape-changing members are driven by the control unit to change shape, the first total length decreases by an amount that the second total length increases.

67. The apparatus according to claim 66, wherein at least one of the shape-changing members comprises a hydraulic actuator.

68. The apparatus according to claim 66, wherein at least one of the shape-changing members comprises an electromechanical actuator.

69. The apparatus according to claim 68, wherein the electromechanical actuator comprises an electromagnet.

70. The apparatus according to claim 68, wherein the electromechanical actuator comprises a piezoelectric element.

71. Apparatus for compressing at least one chamber of a heart of a patient's body, the apparatus comprising:

one or more shape-changing members;

a control unit, adapted to drive the shape-changing members to change shape; and

a band, an effective length of the band being adapted to surround a portion of the heart and to shorten responsive to the control unit driving the shape-changing members to change shape, whereby to enhance contraction of the heart.

72. The apparatus according to claim 71, wherein the band is adapted to be looped around at least one of the shape-changing members.

73. The apparatus according to claim 71, wherein the band is adapted to be looped a plurality of times around at least one of the shape-changing members.

74. The apparatus according to claim 71, wherein the band is shaped to define a plurality of discontinuities thereof, and wherein, for each discontinuity, one of the shape-changing members is coupled between an edge of the band on one side of the discontinuity and an edge of the band on another side of the discontinuity.

75. The apparatus according to claim 71, wherein the band is shaped to define at least one discontinuity thereof, and wherein one of the shape-changing members is coupled between an edge of the band on one side of the discontinuity and an edge of the band on another side of the discontinuity.

76. The apparatus according to claim 75, wherein a plurality of shape-changing members are coupled between the edges of the band.

77. The apparatus according to claim 71, wherein at least one of the shape-changing members comprises a hydraulic actuator.

78. The apparatus according to claim 77, wherein the hydraulic actuator comprises a balloon.

79. The apparatus according to claim 77, wherein the hydraulic actuator comprises a piston and a cylinder.

80. The apparatus according to claim 79, wherein the control unit is adapted to drive fluid into the cylinder to cause the effective length of the band to shorten.

81. The apparatus according to claim 79, wherein the control unit is adapted to draw fluid out of the cylinder to cause the effective length of the band to shorten.

82. The apparatus according to claim 71, wherein at least one of the shape-changing members comprises an electromechanical actuator.

83. Apparatus for compressing at least one chamber of a heart, the apparatus comprising:

one or more inflatable elements;

a pump in fluid communication with the inflatable elements; and

at least one band in mechanical communication with the inflatable elements, a portion of the band adapted to be placed around at least a portion of the heart in mechanical communication with the portion of the heart,

the inflatable elements arranged such that when the inflatable elements are inflated by the pump, the inflatable elements apply more force to the heart via shortening of the portion of the band than via expansion of the inflatable elements against the heart.

84. Apparatus for compressing at least one chamber of a heart, the apparatus comprising:

a pump; and

one or more inflatable elements, adapted to be placed around at least a portion of the heart, and in fluid communication with the pump, such that when the inflatable elements are inflated by the pump during a cardiac cycle, a peak reduction in volume of the heart is at least 200% of a total volume of fluid pumped into all of the inflatable elements by the pump during the cardiac cycle.

85. Apparatus for compressing at least one chamber of a heart, the apparatus comprising:

an implantable compression system; and

a battery sufficient for supporting at least 1 hour of normal operation of the compression system between recharging cycles,

wherein a total mass of the apparatus is less than 300 g.

86. Apparatus for compressing at least one chamber of a heart, the apparatus comprising:

an implantable compression system; and

a battery sufficient for supporting at least 1 hour of normal operation of the compression system between recharging cycles;

wherein a total volume of the apparatus is less than 300 cc.

87. Apparatus for compressing at least one chamber of a heart, the apparatus comprising:

an implantable hydraulic compression system,

wherein the system comprises a sleeve attached to the heart, and wherein a mass of the sleeve including any fluid therein does not exceed 100 g at any phase of the heart contraction cycle.

88. The apparatus according to claim 87, wherein the mass does not exceed 70 g at any phase of the heart contraction cycle.

89. The apparatus according to claim 88, wherein the mass does not exceed 50 g at any phase of the heart contraction cycle.